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HIGH-SPEED FLIGHT
AND THE MILITARY

by

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In Partial Fulfillment of the Graduation Requirements

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Preface

This paper addresses how future high-speed flight vehicles could support military operations. High-speed flight, for the purposes of this paper, encompasses both sustained supersonic cruise and hypersonic flight (Mach 5 or faster). Research indicates that environmentally-friendly supersonic transports and hypersonic technologies are within twenty years of maturation. I believe now is the time for the military to start building a “high-speed roadmap” toward their future application. Commercial aerospace industries, with assistance from NASA, are developing a promising supersonic transport. I also believe that such a transport could enhance future military flight operations as well as provide a solid foundation for hypersonic flight. This paper uses somewhat of a “brainstorming” or “thinking out of the box” approach to this issue. My intent was simply to *introduce possibilities* and it is my hope that this will stimulate further thinking by those who are responsible for the advancement of aerospace power. As a fair warning, this paper has several technical descriptions of research and engineering concepts and some aviation-specific terminology. However, the paper is designed to be very readable for those with limited technical backgrounds as most of the “techno-speak” merely enhances a more general, easy-to-grasp concept.

I cannot say a big enough “thanks” to LtCol Idell for her support, attention to detail, and for her seemingly endless supply of contacts and “experts in the field” whose expertise was invaluable.

Abstract

This paper makes a qualitative assessment of NASA's High-Speed Research program and its associated High-Speed Civil Transport (HSCT) program to answer the question of whether or not this Mach 2.4-class, 300 passenger transport and its supersonic business jet (SSBJ) counterpart could have value to future military operations. This research found that supersonic transports such as the HSCT and the SSBJ could be in production within 10-20 years. Based on the projected operating capabilities of the HSCT and the SSBJ, this paper presents several plausible military missions these vehicles could support. The list includes: rapid transoceanic support of AEF operations and priority airlift missions; aeromedical support; CINC and distinguished visitor movement, special operations support, and crisis response support.

This paper then presents a plan for which a future bomber could be developed based on the technology and research generated by the High-Speed Research program. This bomber would provide a critical next-step towards achieving a hypersonic flight (Mach 5 or faster) vehicle. Military investment in the High-Speed Research program would yield benefits beyond a next-generation bomber. It would also stimulate the civil aerospace sector's production of the HSCT and thereby provide both the military and the nation quicker access to a supersonic transport capability.

Chapter 1

Introduction

The void created in the last 30 years in all aeronautics and space endeavors is the vacuum that nature abhors. It will be filled, and the signs are in the wind that we will go into the 21st century with a vigor not abundantly evident just a few years back.

—A. Scott Crossfield
First man to fly Mach 2 and Mach 3
Aviation Week and Space Technology, 13 October 1997.

As the dawn of a new century approaches, high-speed flight, which includes both supersonic cruise and hypersonic flight, is gaining more attention from commercial industry, the military and the National Aeronautics and Space Agency (NASA). Modern research and development have brought state-of-the-art advances in propulsion technology, computational fluid dynamics and materials that make high-speed flight a viable and profitable avenue for both the commercial industry and the military. Under the High-Speed Research (HSR) program, NASA and the commercial aerospace sector are currently developing a Mach 2+ High-Speed Civil Transport (HSCT) aircraft, which is projected to be operational early in the next century. Though the Concorde already hauls passengers just over Mach 2, its commercial success has been dismal—a marginal load factor, high operating costs, and environmental problems made this an unattractive option for the commercial airlines.¹ The HSCT program believes it can solve these problems with modern technology and engineering. Chapter 2 of this paper will describe and assess the

HSR/HSCT program. Chapter 3 will address whether or not such a vehicle would be compatible and viable for supporting military operations, and if so, in what manner.

NASA's High-Speed Research program brings more than just a supersonic transport to the commercial market, it provides many key-enabling technologies that could be used for other advanced projects. One such project may be a future bomber for the USAF. This year, the USAF is to deliver to Congress a "bomber roadmap" which is to address how it plans to equip and perform long range strike missions well into the next century. Options range from buying additional B-2s, at close to \$1 billion per aircraft, to building both manned and unmanned hypersonic vehicles. However, a bomber built on the technologies of the HSR program and closely mapped to the HSCT could potentially save a significant amount of money while providing an important intermediate "stepping-stone" on the road towards hypersonic flight. In the mid-eighties, a program called the National Aerospace Plane (NASP) tried to produce a hypersonic vehicle in a quest to provide both commercial and military operators cheap access to space via a single-stage-to-orbit aerospace vehicle. This vehicle was to use a revolutionary air-breathing, hydrogen powered engine. By the early nineties, NASP was floundering and soon to die. Much of its demise was a result of changing political priorities and program goals that presented *too many technological obstacles and were too ambitious*—carrying high risk and cost penalties.² Chapter 4 describes how an incremental approach towards hypersonic—developing a supersonic bomber based on the HSR program, and on a parallel track, developing limited-objective hypersonic capabilities such as engine and missiles technologies could be the key for a successful future hypersonic air and space force.

Chapter 2

An Overview of the High-Speed Civil Transport Program

The passenger jet of the future is taking shape. NASA and its industry partners have developed a concept for a next-generation supersonic passenger jet that would fly 300 passengers at more than 1,500 miles per hour—which is more than twice the speed of sound. As envisioned, the High-Speed Civil Transport (HSCT) would cross the Pacific or Atlantic in less than half the time of modern subsonic jets, and at a ticket price less than 20 percent above comparable, slower flights.

—NASA's High-Speed Research Division
NASA's High-Speed Research Program—Developing a Future Passenger Jet, 1998

Historically, American aerospace industry has enjoyed the lion's share of the civil transport market. But over the past 15 years, European Airbus Industries has been slashing away at the US market share. Airbus now has approximately 48% of the market share in terms of new signed purchase agreements. After conducting market studies, the US industry became keenly interested in producing a productive, mid-sized (300-passenger) transport that could push it back into the market lead. Speed is one way in which the productivity and marketability of a transport can be achieved. Using NASA contract money in 1986, both Boeing and McDonnell Douglas found promise for a conventional-fueled, Mach 2.0-2.4, 5,000-6,500 nautical mile range, 250-300 passenger transport. Economic studies by both companies revealed significant passenger demand in the early 21st century. The projected market for high-speed civil transports (HSCT) was on the order of 500 aircraft between the years of 2000 and 2015—which translates to more than 200 billion in sales and a potential for 140,000 new jobs in the United States.³ In order to make this

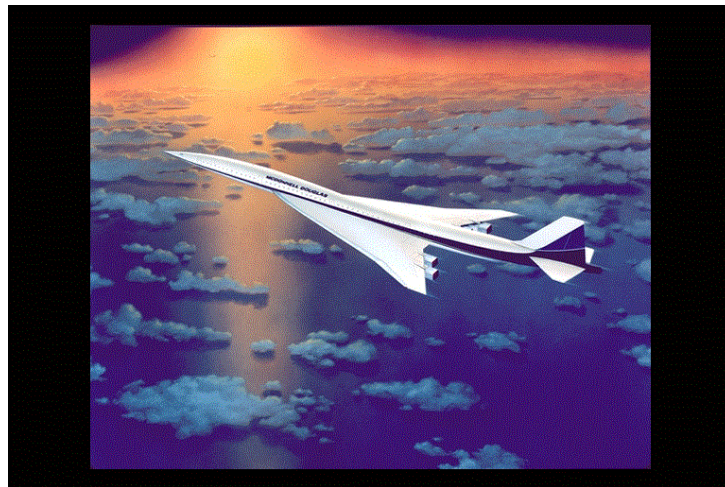
critical, high stakes market attainable for the US aerospace industries, NASA became their “partner” in 1989 to help develop critical required technologies for high-speed flight.

NASA’s High-Speed Research Program

The success of this venture was contingent on producing jets that could meet stringent noise and environment requirements, have low operating costs, and quick turn times. In 1989, NASA and supporting aerospace companies began the High-Speed Research (HSR) program to develop “enabling technologies” to meet these requirements. The HSR program was divided into two phases: Phase 1 and Phase 2. The \$280 million Phase 1 program was to focus on development of technological concepts for environmental compatibility, followed by the \$140 million Phase 2 in 1994. Phase 2 was to demonstrate the environmental technologies as well as define and demonstrate selected, high-risk technologies for economic viability.

High-Speed Research Phase 1 (HSR 1): Emissions, Airport Noise and Sonic Booms

In December of 1995, a single aircraft concept was chosen by NASA as a common reference point for HSR technology. This aircraft, the Technology Concept Aircraft (TCA), served as a model to work technological issues. The TCA has since evolved from separate Boeing and McDonnell Douglas HSCT designs—fusing the best of both into one superior aerodynamic model. Boeing’s model used a wing design that enhanced slow speed aerodynamics which in turn would down-size the engines and thus reduce takeoff noise. McDonnell Douglas’ concept favored reduced drag at cruise speed (Mach 2.4), thus minimizing fuel consumption rates. Engine design and performance estimates were based on both Pratt & Whitney and General Electric (GE) designs.⁴ See Figure 1 for a depiction of both the McDonnell Douglas and Boeing designs.



Source: NASA, Image # AC93-0294-1.

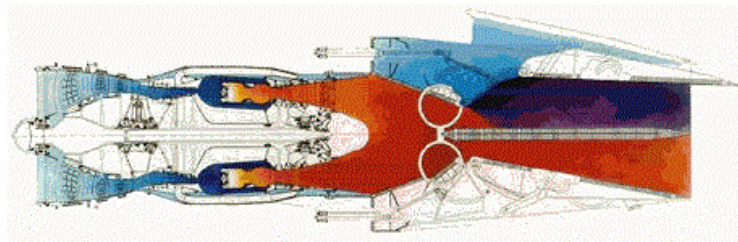
Figure 1. HSCT Design Concepts: Boeing (top), McDonnell Douglas (bottom)

Sonic Booms. One of the significant roadblocks to the ill-fated US SST program of the early seventies was noise control—both in jet noise and sonic booms. Sonic booms are created as an aircraft “breaks the sound barrier” creating a trailing shock wave in its wake. As this shock wave propagates to the ground, property and people may be damaged and injured by its effect. Initial sonic boom research was directed towards reducing the boom signature to an acceptable over-land level. Configurations were designed via computational fluid dynamics and predictions validated using wind tunnel and SR-71 Blackbird flight tests. Significant reductions in shock wave intensity were made, but to do this a radical aircraft configuration was required and made

economic viability unattainable.⁵ Researchers then went back to a more “economic” aerodynamic design that would be limited to subsonic flight overland.

Community Noise. The design of an advanced HSCT must also include airport noise reduction goals. Since this aircraft will not be operating until the next century, the potential for even more stringent noise restriction regulations must be considered. It is reasonable to expect that this transport must be at least as quiet as today’s fleet average—the HSR program has set the noise level goals at 3-5 decibels (dB) below current Federal Aviation Administration (FAA) standards. The primary source of noise is produced during the takeoff phase, from the high-speed hot exhaust. Turbojets are notoriously noisy, as with the Concorde—although this engine delivers excellent high-speed performance. On the other hand, high-bypass fan engines, called “turbofans” used by modern commercial transports produce very little noise, but will not deliver supersonic speeds. Turbofans are quiet because a significant portion of their thrust is from the large front fan. Much of this engine’s airflow bypasses the combustor, flowing around its core, then blanketing the noisy exhaust gasses with cool, quiet air. The HSCT program is developing a compromise cycle engine called the “mixed-flow,” or “variable-cycle” turbofan.⁶ This powerplant will have both turbofan *and* turbojet features. To slow the high-speed jet exhaust, thereby reducing noise levels, the engine uses a moderate bypass ratio. However, this alone is not enough to suppress the noise. A “mixer-ejector nozzle” was added to help—this nozzle directs freestream air into the engine’s core jet exhaust, resulting in a slower, cooler, and quieter exhaust. This mixing technique can suppress jet noise to *one quarter* of the Concorde’s noise output.⁷ To keep the nozzle at a minimum weight advanced materials and manufacturing processes that are still under development will be used. Some of these materials include: ceramic matrix composite acoustic tiles for reducing mixing noise, gamma titanium aluminides for the

flap, thin wall castings made of superalloys for the mixer, and thermal blankets to protect the backside of the nozzle.⁸ Figure 2 depicts the HSCT's variable-cycle turbofan engine.



Source: NASA Lewis Research Center, High Speed Systems Office.

Figure 2. Supersonic Propulsion System for HSCT

To reduce the noise around airports, a high-lift wing design can be used. High-lift leading and trailing edge wing systems would reduce thrust required for takeoff and landing thereby reducing noise levels. These advanced high-lift design concepts will more than double the low-speed lift-to-drag ratio relative to the Concorde when combined with programmed procedures such as automatic flap and throttle settings.⁹

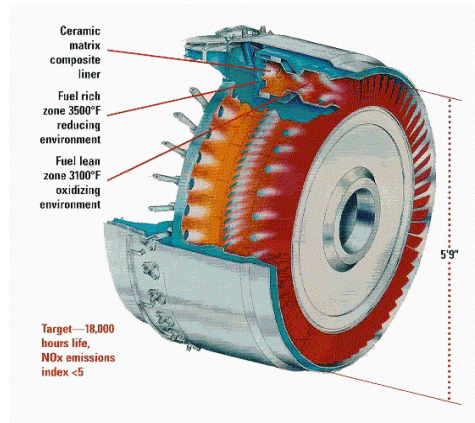
Atmospheric Impact and Emission Reduction. Depletion of the stratospheric ozone is probably the most publicized issue concerning high altitude transportation. The ozone layer protects life on earth from the sun's ultraviolet rays by absorbing those rays. The HSCT is designed to operate at approximately 55,000-60,000 feet—which also is near the maximum density of the stratospheric ozone. Here, nitrogen oxides (NO_x) would be expelled from the transports exhaust. Nitrogen oxide, with energy from ultraviolet rays, break down and deplete the amount of ozone by either delaying or eliminating its rejuvenation process.¹⁰

To address the possibility of ozone depletion by the HSCT, Phase I of the HSR created a sub-program called, "HSR Atmospheric Effects of Stratospheric Aircraft." As part of the program, a team of international atmospheric researchers developed complex computer models of the atmosphere which could predict the impact of various engine exhausts on stratospheric

ozone. In addition, NASA's converted U-2 reconnaissance plane called the "ER-2," was used along with weather balloons to make global measurements of the stratosphere and identify photochemical, radiative, and dynamic features of the stratosphere.

The ER-2 also tailed the Concorde and measured the near-field atmospheric exhaust profile. From this data, researchers were able to calibrate their 2- and 3-dimensional photochemical transport models. As an input to these atmospheric models, a global engine exhaust database was defined. Departure and arrival airports from which the HSCT would most likely operate (called city-pairing) along with corresponding flight trajectories were also input to this model.

The key to reducing the exhaust output of NO_x is to burn the fuel either rich or lean (in terms of air-to-fuel ratios). Current jet engines burn fuel at near stoichiometric air-to-fuel ratios, producing high levels of NO_x. NASA and industry looked at both the rich and lean burn techniques. See Appendix A for more information on these burn techniques. For both burn concepts, developing a satisfactory engine liner material is a major challenge because active cooling with air changes the mixing and chemistry of the burn which are critical to low NO_x emissions. Hence, ceramic matrix composites are the leading candidate materials for the 3,500°F operating environment and 9,000 hour life cycle. These materials have been demonstrated at design temperatures and near operational load conditions using accelerated test techniques, Figure 3 depicts the temperature profile in the engine combustor section.¹¹



Source: NASA Lewis Research Center, High Speed Systems Office.

Figure 3. Combustor Concept for HSCT

High Altitude Radiation. High altitude radiation is of either a galactic or solar origin. Galactic rays are made up of energy, which penetrates deep into the earth's atmosphere. Solar rays are less penetrating and are generated by solar flares, but may be very intense for short periods of time.¹² With its beginnings in HSR Phase 1, NASA recently completed a study based on the National Council on Radiation Protection, which suggested that a high-altitude radiation data base be developed to properly characterize the radiation environment in which the HSCT will operate. NASA once again used its ER-2 aircraft to measure cosmic and solar radiation at altitudes between 50,000 and 70,000 feet. This data is being used to characterize and define the effects of high altitude radiation on both the flying public and HSCT flight crew. The radiation dose was found to be about double of what current subsonic airliners flying at typical altitudes (40,000 feet) are exposed to. However, the typical passenger will actually receive less radiation exposure than on today's subsonic transports because of the significantly reduced travel times. NASA still has concerns for the flight crew, especially pregnant members. Radiation exposure can best be managed by crew rotation scheduling based on predicted and known radiation levels found through the NASA study.¹³

High-Speed Research Phase 2 (HSR 2): HSCT Technology Development

In 1994, NASA embarked on the seven-year HSR 2 Program developing select, high-risk technologies for an economic HSCT. The specific areas of interest are: development of advanced aerodynamics, an electronic flight deck, light weight structures, high endurance and efficient engines. Boeing-McDonnell Douglas (now merged), GE Aircraft Engines, and Pratt & Whitney are the primary aerospace industries producing joint research for the development of enabling technologies for this next-generation supersonic airplane.

Configuration Development. In 1993, design goals of the HSCT were further defined and a 300 passenger, 5,000 nautical mile (NM) range transport was agreed upon. Table 1 outlines design specification details.

Table 1. HSCT Design Requirements

1. Tri-class seating	300 passengers
2. Takeoff Gross Weight	753,000 lb.
3. Empty Weight	302,000 lb.
4. Fuel Capacity	59,000 US Gal.
5. Cargo Volume (Lower hold)	2,000 cu. ft.
6. Cruise Speed	1,600 mph (Mach 2.4)
7. Altitude	60,000 ft.
8. Range	5,000 NM

Source: Boeing, *HSCT Airport Compatibility Brochure*, 1999, 14; on-line, Internet, 12 March 1999, available from <http://www.boeing.com/assocproducts/aircompat/hsct.htm>.

Advanced Aerodynamics. HSR 2's aerodynamic research has focused on developing concepts and validating design and optimization methods for correct aircraft configuration and quality aerodynamic handling. State-of-the-art computational fluid dynamics have optimized fuselage, nacelle, empannage, and wing geometry during supersonic cruise. Optimal design parameters were based on an 85 percent supersonic over water and 15 percent subsonic over land mission profile.¹⁴

One way NASA looked to reduce drag and increase the HSCT's fuel efficiency was via supersonic laminar flow control. This technique would use active suction through millions of tiny laser-drilled holes on the wing surface. Suction would reduce the turbulent air flowing very close to the wing's surface, leaving it smooth, or "laminar." In flights with NASA's F-16XL, researchers obtained supersonic laminar flow using this technique over a majority of the wing's surface, see Figure 4.



Source: NASA Dryden Flight Research Center.

Figure 4. Active Experimental Wing Section: Upper Surface of Left Wing—F-16 XL

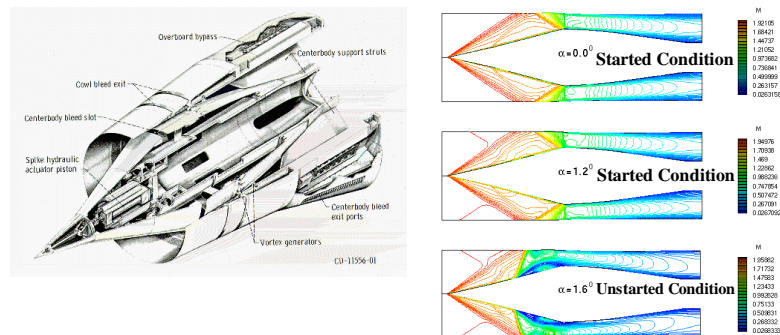
Even with the weight of the suction device and the power it would draw off the HSCT's engines, experts believe that the overall aircraft weight would still be cut by 6.5 percent. This weight saving would come from efficiency gains produced by the active flow control system—allowing the plane to carry and burn less fuel. Experts also believe that suction would reduce overall emissions and operating costs.¹⁵ Though laminar flow control looked very promising, NASA and industry elected to drop this program from the HSCT because technology demonstrations of the subsystems, laser drilled holes through composite wing material, and actual HSCT wing size laminar flow verification are not yet completed.

The HSCT design presents significant challenges in flight control technology and guidance systems. Simulation projects like the “High-Speed Civil Transport-Douglas” (HSCT-D 2) carried-out by NASA/Ames and the Douglas Aircraft Company investigated flying qualities of the HSCT with the following objectives: developing control laws, evaluating the longitudinal control modes, examining the “back-side of the power curve” characteristics, HUD (heads-up display) effects, speed brake use, new auto-throttle design, and lateral-directional flying qualities. Researchers were successful in meeting all project goals using six pilots and a total of 850 data runs in a motion simulator.¹⁶ Additionally, the US Air Force’s Total In-Flight Simulator (TIFS) airplane has been programmed to make the TIFS airplane fly the way engineers think the real HSCT will fly. A series of flight tests will investigate the HSCT flight controls, pilot displays, approaches and landings and low-speed maneuvering near the airfield. Engineers will vary the way engines and flight controls respond to pilot input.¹⁷

Engine Development. The goal of HSR 2’s Engine Technology Program was to actually develop the materials and structures for a sustained supersonic cruise engine. Specifically, the program was to produce an engine along with the air inlet system, combustor, and nozzles (with noise suppressers). One significant challenge that still lies ahead for Phase 2 are scaling up the ceramic matrix composite nozzle and other components previously mentioned to design size.

The supersonic environment poses additional obstacles that are not present for its subsonic transport counterparts. For example, the HSCT’s inlet system needs to operate at high efficiency over a large stability margin. A phenomenon known as inlet “unstart” is an extremely important issue to engine designers. An inlet unstart will occur if the terminal shock is displaced from its optimal location within the inlet. Inlet unstarts result in transient forces on the aircraft that would effect passenger comfort and safety and may also cause engine surges. NASA engineers have

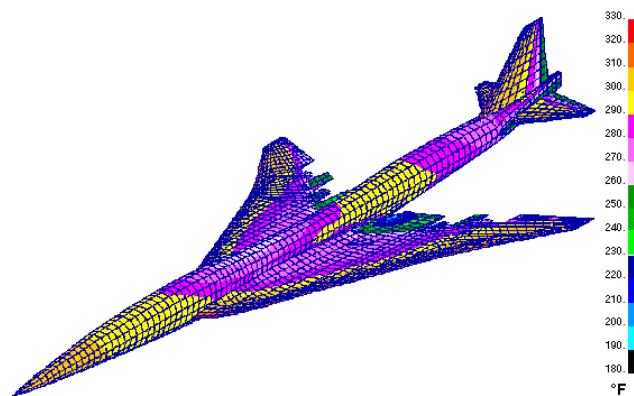
developed complex computational fluid dynamics (CFD) programs to predict 3 dimensional HSCT inlet flow fields to counter this problem.¹⁸ Figure 5 shows a HSCT inlet system and its associated CFD predicted flow fields at varying angles of attack.



Source: Rutgers University. *Design Optimization for HSCT Inlet Operability with Angle of Attack*, 1997.

Figure 5. CFD Flow predictions of a HSCT Inlet

Structures and Materials. HSR 2 selected the advanced materials and structural concepts for fabrication and testing. This material must support an airframe lifetime of 60,000 hours at sustained temperatures approaching 350° F, see Figure 6.



Source: S.J. Hatakeyama, *High-Speed Civil Transport Home Page*, 1996.

Figure 6. Temperature Profile of the HSCT at Mach 2.4 Cruise

Additionally, the key to the HSCT's economic feasibility is minimizing weight and manufacturing costs while retaining structural strength and durability. A 30 percent weight reduction relative to the Concorde is desired.¹⁹ Many of the structural concepts studied in the

early part of the HSR program have been weeded out. Engineers have narrowed down design candidates to two finalists. Testing can now expand to large sections and panels. In two recent tests, 40 inch long by 80 inch wide panels were subjected to over 400,000 pounds of force before they failed. The program will eventually test 12 feet by 20 feet fuselage sections. The Combined Loads Tests facility is being constructed for the application of forces, moments, pressure, and temperature loads to validate structural concepts and analytical techniques.²⁰

Flight Deck. As part of the HSR program, NASA engineers are developing the technology that would replace the forward cockpit windows in future supersonic passenger jets with large sensor displays. These displays would alleviate the need to “droop” the nose for forward visibility during the takeoff and landing phase, hence reducing airframe weight. Appendix B outlines some of the remarkable advancements NASA has made in synthetic vision systems.

The HSCT Forecast

NASA and the civil aerospace industries seem to be building this program on a solid foundation. One obvious question still remains will this jets actually reach the production phase? And if so, when? In the mid-nineties, a poll of aerospace experts was conducted which solicited their educated answer as to when the flying public could expect to fly on the HSCT, paying only 10% above what a normal, subsonic fare would cost. All experts believed the HSCT would be produced, with the average predicted date of service being 2014, see Table 2. However, in a personal interview with a Boeing HSCT official, he indicated that the production of this jet might be another twenty years coming. This delay is mainly because of problems recently found in meeting the “better than current standards” noise requirement and the, “not more than 10% over standard fare-ticket price” program goal. A possible solution to this will be addressed in Chapter

4. With these problems in mind, the HSCT official indicated that Boeing is becoming interested in developing a supersonic business jet—a program in which noise and ticket prices are of small concern. Chapter 3 will highlight some details of this jet.

Table 2. HSCT Forecast

	HSCT Service Date (paying a 10% premium for this service)
Derfchin	2020
Grey	2010
McDonnell Douglas	2005
Scott	2025
Williams	2010
<i>Bottom Line</i> (sample average)	2014

Mike Derchin: Airline and aerospace analyst, Tiger Management.

Jerry Grey: PhD; director of aerospace and science policy, American Institute of Aeronautics and Astronautics.

McDonnell Douglas Corporation:

Bruce Bunin: Director of high-speed civil transport program;

George Orton: Program manager of Hypersonics Center of Excellence, Phantom Works;

Mark Page: Technical program manager of blended-wing-body

Kelly Scott:* Transportation analyst, Office of Technology Assessment, US Congress.

Louis J. Williams: Director of high-speed research division, NASA

**Kelly Scott's opinions are her own and are not those of the OTA or its Technology Assessment Board.*

Source: David Pescovitz, "The Future of Airplanes," *Wired Magazine*, Issue 3.09, September 1995, 1.

Chapter 3

Military Use of the HSCT

Much of the support information for this chapter was derived from interviews with industry and USAF transportation specialists. It must be realized, however, that their opinions are personal, unofficial comments and may not necessarily represent official policy. This chapter asks *where* and *how could* this supersonic transport be used to the benefit of the US military. To best answer this question, one should take all the capabilities of the jet into consideration and then distill-out those *unique* capabilities that would enhance military operations. The HSCT brings nothing new in terms of range, passenger and cargo capacity, or operational cost. *It simply offers speed.* Obviously, the value of this speed is bounded by the operational parameters of the jet. In other words, this speed comes in a vehicle with decent range (5,000-6,500 nm) and passenger capacity (300), limited cargo capacity (no out-sized), and is more expensive to operate than a conventional airliner. In order to capitalize on the HSCT's speed, it is fair to assume that overland supersonic flight will be restricted by many nations, *hence it is best suited as a transoceanic vehicle.* Also, for this vehicle to support military operations, it must be able to operate from a host of military fields.

Military Airfield Suitability

According to a chief HSCT engineer at Boeing, this transport is designed to fit into and operate within the existing civil airport infrastructure—no additional modifications would have to be made. This would also hold true for military fields—if it is suitable for KC-135s and KC-10s, the HSCT should be able to operate in and out of the airfield as well. Boeing did caution, however, that the HSCT had a significant turn radius of 110 feet, which may restrict its operations from fields with limited ramp space and tight taxiways.²¹

Although this unique enhancement in airlift capability would be attractive to the military, one must consider the most cost efficient way to use such a transport.

Should the Military Buy or Contract the HSCT?

Whether to purchase the HSCT or lease the aircraft depends on multiple factors. The first is *cost*, and the HSCT will be expensive. In fact, Peter Radloff of Boeing's HSCT development team foresees the actual production of HSCT as a multinational consortium effort to help defray the cost. He predicts that the HSCT will cost approximately twice as much as a comparable subsonic transport. However, in the civil market, the HSCT pays for itself in producing nearly twice the sortie capability as compared to subsonic transports in long haul operations. This may not be the case when supporting military operations where routing, demand, and airfield support capabilities may fluctuate producing less efficient operations. If purchased, there would also be a significant expense in creating a military infrastructure to support the supersonic transport. Maintenance facilities, flight instruction, simulators, and additional pilots would all have to be brought on line. *Configuration* is the second factor—the HSCT is optimized for passenger haul, not military equipment delivery. Its narrow fuselage would prohibit over-sized and out-sized

cargo, and its small doors coupled with a lack of roll-on/roll-off capability would further limit its military potential. Though Boeing said that a cargo variant was being studied, specific details were not available.²²

However, there are still some advantages to purchasing the HSCT. If purchased, the military could have the aircraft configured to better suit military cargo haul—floors can be reinforced, doors can be modified (as with the KC-10 and KC-135), and floor plans can be optimized. Additional fuel capacity could also be added, extending its range so that it could fly non-stop from the continental United States (CONUS) to any major regional conflict (MRC). A cargo-carrying range of at least 7,000 nautical miles would satisfy most scenarios. According to NASA researchers, the HSCT provides for early growth to both a stretched and extend-range version capable of travelling 6,500-7,000 nautical miles.²³ With this increased range, the US Transportation Command (USTRANSCOM) could use this transport in a manner similar to how the “Desert Express” aircraft were used during DESERT SHIELD/DESERT STORM. Desert Express used C-141s and KC-135s in a daily shuttle operation between the CONUS and Saudi Arabia. Because of their long-range capability, these aircraft were able to fly non-stop into theater, which reduced the delivery time of mission critical parts from approximately ten days to as little as 72 hours.²⁴ Owning the transport would also release the USAF from contract restrictions and would increase scheduling and mission flexibility of the transport. If the jet were a military asset with military pilots, issues such as flight into combat zones and delivery of hazardous cargo would become easier to manage. However, if one were to measure the advantages and disadvantages of owning the transport on a cost versus benefits scale, it would seem that the HSCT’s notable lack of a “military-specific” design tips the scale away from a viable purchase option. This does not imply, however, that it would not be advantageous for the

military to operate the HSCT under the right circumstances such as within a contract agreement. It is this author's opinion that contracting-out HSCT operations would have two primary advantages for the military. The first advantage would be that a contract agreement would almost certainly be less expensive than owning the transport as the military would not be responsible for the purchase, maintenance, training, or sustainment of a limited-use aircraft. The second advantage to contracting HSCT operations is selective usage. Contracted HSCT operations could be limited to only those missions where the benefits of *speed are worth the extra cost*. When interviewed, US TRANSCOM officials also postulated that contracting HSCT operations seemed the "logical" choice for the military, and most likely under the Civil Reserve Air Fleet (CRAF) program.²⁵

The Civil Reserve Air Fleet (CRAF) and the HSCT

Should the HSCT become part of the civil transport fleet, the CRAF program could provide reliable, economic, on-demand access to the transport. A special contract could be drafted in which the military (USTRANSCOM) could control and schedule the HSCT to support those operations where speed of delivery and operations tempo require its use. A brief overview of the current CRAF program will help understand how the HSCT would fit in.

The CRAF is a voluntary contractual program created by a Presidential Directive in 1952 and codified by the Federal Aviation Administration (FAA) in 1958. This program is a cooperative effort between the Department of Defense (DOD) and the Department of Transportation (DOT). The DOD manages the CRAF contract while the DOT coordinates and allocates civilian aircraft for wartime activation as well as provides wartime insurance for the carriers.²⁶ The CRAF is designed to augment military airlift with civil carrier resources during increased activity. However, even when military airlift is not at an increased level, the CRAF

program is still used for normal, day-to-day airlift operations. In order for civilian carriers to win military airlift contracts, CRAF participation is usually required. CRAF participation is quite lucrative for civil carriers and currently the program is over-subscribed.²⁷ An estimated \$600 million worth of business will be awarded this year under the Air Mobility Command (AMC) International Airlift Service Contract and another 1.2 billion in General Services Administration (GSA) City Pairs and GSA Domestic Small Package business is reserved for CRAF members.²⁸ All told, the CRAF provides more than 50% of AMC's strategic (long-range international) airlift during periods of increased activity. In fact, during these times the CRAF handles 93% of the long-range passenger movement. To attract some of the faster and more capable transports, the military awards "mobilization value points" to those carriers who provide jets with good speed and payload capability.²⁹ The carrier's annual share of the AMC airlift then depends on the total number of mobilization value points earned. Finally, the CRAF has three segments: International, Aeromedical, and National. The Aeromedical Evacuation Segment currently supplements the organic military fleet by providing global evacuation capability using Boeing 767 aircraft—there are 50 aeromedical conversion kits stored in Texas.

It is under this CRAF program that US TRANSCOM foresees a potential "niche" for the HSCT.³⁰ Civil carriers would provide HSCT services, and as typical with using the CRAF, its primary use would be for long-range passenger movement as well as bulk and sustainment cargo. Military equipment, ammunition and parts required for squadron deployments would still be transported using military airlift, as most of this equipment requires specialized aircraft. Civil aircraft are also at a disadvantage when moving military equipment because they usually do not have adequately stressed floors to handle the heavy loads, nor the design or size to handle out-sized cargo.

Normally under the CRAF agreement, USTRANSCOM specifies what its needs are in terms of capacity and the carrier is basically free to meet the need with a type aircraft of its choosing. Mobilization value points are the carriers' only incentive to provide the faster and more capable aircraft. However, this method of business would be too unreliable for securing flexible, on-demand access of a HSCT. According to a HQ AMC official, it is reasonable to assume that an adjustment to the CRAF contract could be made that would allow the USAF to specify the *type* of aircraft required.³¹ With this being done, a lease agreement could be set-up with a carrier, or carriers, to provide dedicated supersonic service to the military. This contract might also provide for a combat zone *inclusion* clause along with specific guidance regarding the transport of hazardous cargo. Along with this, a special training program could be established for the contracted pilots so they are better equipped to handle military support missions.

Let us assume that the military is able to gain access to the HSCT in some fashion or another and we now will turn our focus to how such a supersonic jet could potentially be used by the military. The intent of the following paragraphs is to “brainstorm” the spectrum of possibilities, presenting some of the major considerations associated with each potential use.

HSCT Support of the Air Expeditionary Force (AEF) and Priority Transoceanic Airlift

Air Force doctrine states “Rapid Global Mobility” as one of its six core competencies. Core competencies are essentially operational concepts that represent the capabilities and expertise of the service. The “*Rapid Global Mobility*” competency refers to the “timely movement, positioning, and sustainment of military forces and capabilities....”³² It further states, “In theaters where only minimal forces are forward deployed, the value of global mobility is maximized since the key to successful contingency operations in the event of hostilities is the capability of the US to rapidly deploy forces to aid friendly nations.”³³ The AEF concept supports this competency by

being able to deploy its forces and generate sorties within 48 hours of call-up. HSCT operations would be able to assist in delivering the pre-deployment troops well before the arrival of the AEF. From a logistics point of view, perhaps the most significant benefit of supersonic transportation is that troops would arrive in theater with less travel fatigue and with more time to prepare for the arrival of aircraft and equipment. Rapid travel time may allow troops to perform critical preparation functions immediately upon arrival in theater rather than having to recuperate from travel fatigue. Rapid delivery of combat flight crews will allow for both adequate rest and mission planning within the 48-hour deployment window as they wait for their combat aircraft to be ferried into theater.

The HSCT could enhance intercontinental airlift operations during contingency operations by cutting overseas transport time nearly in half while doubling its sortie rate. During the initial lodgment phase of an operation, rapidly delivering the “Case 2” forces (fast reaction forces) from the CONUS would quickly give the CINC a credible force. This force could then link-up with prepositioned supplies in theater.

Supersonic Aeromedical Evacuation

CRAF’s Aeromedical Evacuation (AE) Segment supplements the organic fleet by providing global evacuation capability using B-767s fitted with Aeromedical evacuation ship sets (AESS). These AESS kits have litter stanchions that fit into the standard seat-tracks of a passenger airliner. Each set of litter stanchions is approximately four feet in height and is capable of holding three litters. The B-767 is capable of handling 25 stanchion sets for a total of 75 litters. Each litter is provided with oxygen, electrical power, lighting and a call bell. AESS include a liquid oxygen tank, which is stowed in the cargo compartment, a power-converter and a distribution panel located in the cabin area. Should the HSCT become either an Air Force or CRAF asset,

earmarking a portion of the 50 AESS to be fitted on the supersonic transport could have a major impact on Aeromedical operations. The HSCT's inherent speed and range would make the CONUS accessible from much of the world, giving medical personnel greater access to US medical support and supplies. One of HQ AMC's Airlift Analysts highlighted how the AE concept is in a state of transition from forward location care to a "care in the air" concept.³⁴ Under this construct, if the timeframe for patient care at the forward location exceeds approximately one week, it is preferred to move these patients to rear facilities. Moving these patients will include both intra-theater and inter-theater AE lift. This representative postulated that an AE equipped HSCT flying an inter-theater transport role "could provide patients with a better level of care quicker."³⁵ He also indicated that an increased emphasis has been put on en route care and stabilization, but that HSCT operations could give rapid access to state-of-the-art US medical facilities from overseas when needed. Another AE expert at the HQ AMC's Surgeon General's Office postulated that an AE equipped HSCT could be extremely valuable to the military for several reasons. First, the HSCT's large passenger capacity could reduce the number of required supporting AE flight crews. Second, the HSCT's range and speed could shorten the time to required care facilities. Third, and perhaps most importantly, an AE supersonic transport could reduce the "forward care" footprint.³⁶ Forward care facilities located in USAFE and PACAF are required because of speed and range limitations of the AE equipped B-767. Its subsonic speed and 3,300 nautical mile range capability (non-extended range version) is unable to support delivery of patients directly from some major regional conflict areas to the CONUS. The 5,000 nautical mile range HSCT improves this capability. Obviously, if the HSCT could be range enhanced to 7,000 nautical miles, as previously discussed, this would make the HSCT even more attractive to the AE community. It should be noted, however, the newer B-767ER

(extended range) variants rival the HSCT with an advertised range of 6,600 nautical miles. Though B-767ER's range is excellent, its subsonic speed still limits its theater-to-CONUS Aeromedical utility. According the AMC Surgeon General representative, keeping the time between patient care (en route transit) at or under eight hours is important, and hence drives the requirement for forward care facilities. The HSCT's rapid transoceanic transit time, could stay inside this time frame and help reduce our forward medical infrastructure. An extended range AE HSCT could theoretically move patients from Saudi Arabia to the CONUS in five hours (7,000 nautical miles, 2.4 Mach cruise). Realistically, the time would be longer, depending on supersonic flight restrictions, but still likely within the eight hour AE in-transit window.

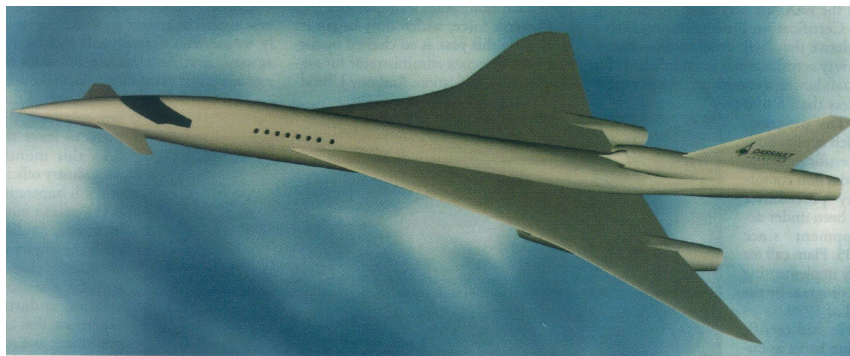
HSCT Operations in Support of MOOTW and National Resolve

According to Joint Pub 3-07, *Military Operations Other Than War* (MOOTW), US forces need to be able to respond swiftly to MOOTW situations "...the ability of the US to respond rapidly with appropriate MOOTW options to potential or actual crises contributes to regional stability."³⁷ JP 3-07 goes on to mention that MOOTW may often be executed under crisis action circumstances. HSCT's rapid delivery of troops, crisis planners and diplomats to the region may increase the US' options in dealing with the problem and may ward off disaster before it strikes.

Finally, HSCT operations could also support our forward military presence. This would demonstrate US resolve and commitment to shaping and responding to global events while accenting our force's capability. Whether it be moving diplomats, commander in chiefs (CINCs), bulk supplies for humanitarian assistance, or 300 Delta Force troops, the HSCT provides the US with a faster crisis response capability and a visible show of our commitment to promoting regional stability.

Introducing the Supersonic Business Jet (SSBJ)

The advancements in supersonics outlined in Chapter 2 have made an impact in the business jet market as well. In late 1997, the French company, Dassault Aviation, with its extensive supersonic fighter expertise, announced that it was in the primary design stage of a SSBJ. From personal interviews with Boeing, they too are now spinning-up a SSBJ program. In fact, their HSCT expert believes it may be on the market sooner than the HSCT as it is able to circumvent most of the problems currently hamstringing this program. With the SSBJ, the noise problem is reduced due to its small size. Also, the revised cost-per-seat goals relegated on HSCT development are not an issue with the SSBJ.³⁸ According to Mr. Rodloff, even though the SSBJ will cost nearly double that of a subsonic business jet, the nature of the business executive clientele being, *“speed is worth the money”* makes it marketable. In September of 1998, Lockheed Martin’s Skunk Works also announced that it was talking with Gulfstream about developing its own SSBJ.³⁹ Design requirements for the Gulfstream-Lockheed jet are: 1.6—2.0 Mach cruise; 4,000 nm range; a stand-up cabin with room for eight passengers and 3 crew members; noise characteristics compatible with future community standards; operability with key general aviation airports. Figure 7 depicts Dassault’s SSBJ which could go into production as early as 2005.⁴⁰



Source: Dassault Aviation.

Figure 7. Dassault's SSBJ

Special Air Missions and the SSBJ. Though USAF's Special Air Missions (SAM) is currently under a contract to purchase Gulfstream G-5s to supplement its current fleet, the SSBJ could further enhance this fleet's capability of transporting CINCs and distinguished visitors (DVs) in the near future. When interviewed, a SAM official indicated that the SSBJ would not be a viable asset to their fleet as most leg segments are of relatively short duration (less than two hours) and over land. Also, he stated that their fleet is in such high demand from civilian DVs (Secretary of Defense, etc.), that CINCs are more often than not excluded from using them due to their lower priority level of access. However, it is this author's opinion that regardless of whether the jet is used by civilians or CINCs, it is still an Air Force responsibility to move them, and a limited-purchase of SSBJs could enhance our national security implementation.

Military use of the SSBJ would make its largest impact with inter-theater movement of CINCs and DVs, especially in transoceanic flights where supersonic operations are unrestricted. Ambassadors, diplomats, peace negotiators, and CINCs who often need to be in Washington in the morning and Bosnia by evening would greatly profit from arriving "fresh" and ready to direct national security policy. During Desert Storm, having access to supersonic, global transportation may have given the State Department the ability to get a negotiation team to the cease-fire agreements being conducted by General Schwarzkopf in Iraq. "'Norm went in uninstructed,' a senior Bush administration official said. 'He should have had instructions. *But everything was moving so fast* [emphasis added] the process broke down'."⁴¹ Considering that a SSBJ purchase would directly benefit those on Capitol Hill, the USAF may be able to get *additional* congressional funding for them. Dassault estimates the purchase cost to be roughly \$50 million per jet—a 5-jet buy would represent a \$250 million outlay—a seemingly reasonable amount

considering the current emphasis placed on employing the diplomatic instrument of power in our national security strategy.⁴²

USSOCOM may also find the small supersonic transport useful to its mission. As this command responds to threats and challenges to US security world wide, supersonic delivery of SOF soldiers could help the US leverage specialized capability in time critical situations. In crisis response, such as hostage situations, counter-terrorism and rescue operations, SOF personnel could be delivered rapidly, with less travel fatigue and more time to plan and deal with the task at hand. One of "USSOCOM's unique responsibilities is to provide SOF with specialized equipment to perform worldwide missions."⁴³ The SSB's unique speed capability may be a consideration for the Special Operations Acquisition Center over the next several years. For larger scale operations, the HSCT could be used to rapidly deliver SOF forces and much of their equipment to the theater of interest.

Notes

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- ²⁰ Ibid., n.p.
- ²¹ Peter Radloff, Boeing Aircraft Co., interviewed by author, 23 December 1998.
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- ³¹ Rousseau.
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Chapter 4

HSCT Technology—A Bridge to the Future

When time is of the essence...and if you have something that positively has to be there overnight, I think we need to look at faster ways to do it.

Gen. Michael E. Ryan
Chief of Staff, USAF

Air Force Magazine, December 1998, vol 81, no 12.

The Road to Hypersonic Flight

The Panel to Review Long Range Airpower has directed the Secretary of the Air Force to present a future bomber fleet upgrade plan to Congress this year. The panel also determined that, “current plans do not adequately address the long term future of the bomber force.”¹ The need for such planning was also driven by the anticipated changes in technology and attrition within the current bomber force—the Air Force’s total bomber force is currently under 250 airplanes.² In the next several months, the Air Force will present to Congress its “bomber roadmap,” describing how the service plans to address this problem. The plan is expected to tilt toward heavy reliance on smaller, hypersonic vehicles—both manned and unmanned. “If the Air Force succeeds in perfecting the critical building-block technologies, these new kinds of aerospace systems could be in place around 2010.”³

Achieving a viable hypersonic capability offers a profound revolution in military affairs (RMA). Such vehicles would give the military a platform for interdiction, surveillance,

reconnaissance, and precision targeting missions. Reconnaissance vehicles would rival satellites in response time for those areas of interest that require an orbital adjustment. Hypersonic bombers could respond anywhere in the world in less than two hours with the added benefit of flexible recall. Such a vehicle would also allow forces to launch weapons further away from enemy defenses, thus reducing their exposure to hostile fire—without paying a penalty in reaction time. The inherent energy of a hypersonic missile would magnify its penetrating power, especially against deeply buried targets.⁴ A single stage to orbit launch vehicle could give our military easy access to high altitude reconnaissance.⁵

Stating what hypersonics can do for the military is easy, actually developing the system is quite another. Recently the Pentagon's director of defense research and engineering said, "there are things on the horizon...that could lead to an air-breathing, high altitude aircraft...it would probably be hypersonic."⁶ He predicted this to be the successor to the B-2. He did caution that this vehicle would "probably be far in the future." He also explained that hypersonic vehicles have a really marginal payload because the "finesse ratio" requires a long, skinny design, "there's no obvious place to put supplies, fuel and weapons...that's their big problem."⁷ In the mid-eighties the National Aero-Space Plan Program (NASP) was inaugurated by President Reagan, whose objective was to produce operational, air-breathing hypersonic vehicles by the late 1990s. However, the program died in the early nineties as the program was plagued by a multitude of problems including interagency coordination and support between NASA and the USAF (NASA had devoted most of its attention and fiscal resources to the space shuttle program), on- and off-again Congressional funding, and the collapse of the Soviet military threat. However, some will argue the most significant problem with the NASP project was that its mission requirement was driving a specific design and the design was limited by technology, *a*

*classic case of dreaming up an idea and then trying to invent unproved technology to make it reality.*⁸ Is the future Air Force bomber going to run into this technology “wall”? Air Force Chief of Staff Gen. Ryan seems to be aware of this potential pitfall and said that the bomber roadmap deliberations have focused on near-term weapons and improvements for the existing fleet of aircraft—a walk-before-you-run approach to hypersonic development. General Ryan did, however, indicate that the follow-on bomber might be a hypersonic plane, which begs the question, “how long will that take?” Air Force Magazine’s senior editor John Tirpak indicated that manned flight could appear around 2015. Other experts in the aerospace field tend to have more pessimistic estimates for the hypersonic timetable, with the average of their estimate being 2027, see Table 3.

Table 3. Hypersonic Space Plane Poll

Derfchin	2030
Grey	2020
McDonnell Douglas	2012
Scott	2050
Williams	2025
<i>Bottom Line</i> (sample average)	2027
See Table 2 For background information of poll members.	

Source: David Pescovitz, “The Future of Airplanes,” *Wired Magazine*, Issue 3.09, September 1995, 1.

Whether hypersonic vehicles appear on the scene in 2015 or 2020, the B-1’s service life expectancy starts expiring in 2010.⁹ This, coupled with the USAF’s emphasis on global attack

and increasing reliance on bombers to enforce diplomacy, creates somewhat of a bomber “vacuum” in the early part of the 21st century. “How badly will the Air Force need replacements for its existing long-range systems? USAF has said it believes the B-52H fleet is ‘technically capable’ of lasting beyond the 2020s, *but if the Air Force could field a system that was faster to target, more effective when it got there, and cheaper to operate* (emphasis added)—which a senior USAF official said has risen to ‘paramount importance among the considerations’—the service would give a serious look at retiring the BUFFs much earlier.”¹⁰

HSCT Technology May Provide the Answer

The answer to “a faster to target, more effective, and inexpensive system” may be found within the HSCT program. This author proposes a “dual track” development strategy for the USAF’s future bomber force, where the first track develops a hypersonic capability and the second track produces a supersonic, global attack strategic bomber based on the design of the HSCT. Developed in parallel, these programs would create a synergistic effect as they cooperated with each other, sharing newly created technological information. NASA already has programs devoted to both areas and could act as the overall curator. Keeping the bomber design closely mapped to the HSCT will create even more incentive within the civil aerospace market—potentially stimulating the rapid introduction of a viable civil supersonic transport using only US resources.

Track I: Limited-Objective Hypersonic Development

“Track I” of this strategy is to develop a hypersonic capability incrementally—where the USAF and NASA continue with limited scope, limited objective projects—those which do not require significant amounts of “yet to be developed” technologies. The building block approach

would be used, where the initial focus would be on propulsion first, followed by military missile application, then finally expanding to single stage to orbit projects. This approach will keep projects from getting bogged-down as they try to overcome a myriad of technological hurdles all at once. Track I's top priority should be the development of the hypersonic engines—the supersonic-combustion ramjet, or scramjet for short, which is the keystone to hypersonic flight. An operational hypersonic missile should be Track I's second priority as it allows for a program of limited, attainable objectives which, in the end, will produce a weapon that may be used on even today's fighter and bomber fleet. The following paragraphs identify some promising “steppingstone” projects in both these areas.

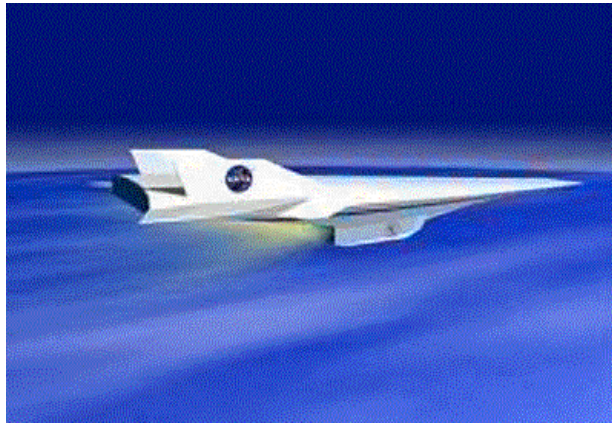
Hypersonic Engines

NASA plans to break-ground and achieve air-breathing, hypersonic scramjet flight tests as early as January of 2000 under a program entitled “Hyper-X.” It is within this program that NASA and the military have come closest to showing inherent potential for meeting the original NASP objectives.¹¹ The Hyper-X program appears to be grounded on the realities of current technologies. Its goal is to achieve Mach 10 by the third and fourth flight test slated for September of 2001.¹² While acknowledging that Mach 15-25 flight meets real operational needs as targeted by the X-30, the Hyper-X team believes this is not affordable and may not be technologically achievable until well into next century. Hyper-X seems to represent a new way of conducting research business for NASA—contracting out work and limiting program objectives to obtainable levels. Hyper-X is to be launched from a Pegasus booster dropped from NASA's B-52 launch aircraft, see Figures 8 and 9.



Source: NASA, Image #C-96-4160.

Figure 8. Hyper-X and Launch Vehicle Attached to B-52



Source: NASA, Image #ED97-43968-3

Figure 9. Hyper-X Vehicle

Hypersonic Weapons

Hypersonic technology requirements are now starting to be driven by current weapon delivery systems such as the B-2, F-22 and the Joint Strike Fighter (JSF). Attention is being given to a notional missile that would cruise at Mach 7-8 and cover 750 nautical miles, fitting under the wing of a fighter, see Figure 10.

A booster would take it to a ramjet start speed of Mach 4. Then, using a fixed-geometry inlet, it will accelerate into the scramjet mode for cruise speed.¹³ A joint effort between the Navy

and Air Force to produce the High-Speed Strike System is set to begin program operations in the year 2000. Initial Operational Capability (IOC) for this joint-venture weapon is estimated to be about 2006-10.¹⁴ A future bomber could be optimized to carry a more powerful, longer-range variant of this weapon.

Track II: The Supersonic Bomber (SSB)

This second track runs simultaneously with hypersonic development and uses the technology that NASA and the commercial aerospace industry have created in the HSCT and SSB program to assist in fielding a high altitude supersonic global attack bomber. Phase II would strive for an operational date around 2015. This bomber would give better balance to the existing USAF fleet—bringing high altitude, high payload capability, long range, and quick global response with flexible recall. Its high altitude cruise and speed capabilities will give it inherent defenses against fairly robust and integrated air defense systems (IADS). Few surface-to-air missiles (SAMs) have the capability to successfully intercept at 60-70,000 feet and very few fighter-interceptors would be able to adequately engage this bomber. *It would also serve as a platform optimized to deliver hypersonic weapons outlined in track I—air-launched cruise missiles (ALCMs) and high-energy penetration devices.* The Mach 2+ bomber could help simplify hypersonic missile engine design, reduce missile weight and increase its range by launching the weapon at high velocity.

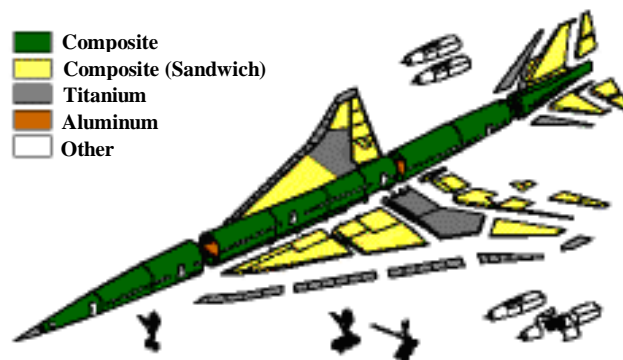
A major issue to address with this bomber is the level of stealth required. If the service decides that stealth capabilities are critical, then some significant body design changes will most likely be required. Wing, fuselage, tail and engine radar signature reduction measures would have to be addressed. The inherent low drag design of the HSCT may aid in the reduction of the radar cross-section signature. The Skunk Works division of Lockheed Martin—which produced the U-2, SR-71 and F-117 stealth fighter, would have the expertise to address this issue as well as

development of radar absorbent skin coatings able to withstand the dynamic temperatures of high-speed, high altitude flight. Lockheed would also be able to expand off this project as they have parallel interests in developing both a SSBJ and a hypersonic X-33 space plane. Though bringing stealth to this bomber would represent many design changes, much of what NASA has developed in the HSCT program might apply and could help reduce R&D costs. Similarly, HSCT technology would bring engineering concepts that address the rigors of constant civilian use to this military bomber—helping to extend airframe and engine life time. If stealth requirements were relaxed, the bomber could be built from the basic airframe and aerodynamic design already in place—huge savings could be made as well as provide direct stimulation to the development of a civil transport.

A bomber equipped with the HSCT's external vision system outlined in Appendix B, would give it robust capability in countering adverse weather and operating from austere locations which may lack navigation aids and instrument landing systems. However, its value would extend beyond technological and performance gains, but would also address the inevitability of attrition. Combat attrition can be significant—during Linebacker II, 15 B-52s were lost in a span of 10 days. Peacetime attrition of the Buff runs at about 1 loss per year and B-1's loss rate stands at one every two years.¹⁵ An inexpensive bomber as described above would be an attractive answer to replacing the 94 aging B-52Hs in the current inventory—23 of which will retire this year.

Development of this bomber may also do more than just stimulate civil supersonic transport production. The supersonic bomber would bring advances in high-speed technology that would provide input and a solid base for the hypersonic "Phase I" endeavors. This bomber and the HSCT would put to task many of the advanced concepts required in both supersonic and

hypersonic flight. As an example, many materials used on conventional transports and bombers, such as aluminum and thermoset composites, do not have the temperature capacity needed by the HSCT or hypersonic flight. Hence, advanced titanium alloys are being developed under the HSCT program with a 20 percent improvement in mechanical properties.¹⁶ Lightweight vehicles are also an important key to high-speed flight. The HSCT's fuselage, strake, empennage, and outboard wing weight will be reduced by using polyimide carbon fiber matrix composites (PMC) which are under development. Accelerated testing and analytical techniques will be used for screening PMCs as it would otherwise take seven years to complete one lifetime cycle. Resin matrix composites and structural adhesives with strength superior to existing materials will be developed for large acreage skin panels, Figure 10 depicts the significant use of advanced composite materials on the HSCT.



Source: S.J. Hatakeyama, *High-Speed Civil Transport Home Page*, 1996.

Figure 10. HSCT Materials Breakdown

These advanced materials and construction techniques would provide the hypersonic program with many tools to aid in its development. Undoubtedly, manned hypersonic vehicles would require a synthetic vision capability and could build upon the bomber's already-developed and "operationalized" system.

Civil Transport Market will Benefit From a New Bomber

Funding a next generation bomber could revitalize HSCT and SSBJ production as well as serve as a much-needed boost for the currently slumped aviation industry. Air Force funding for the bomber along with the combined efforts of several US aerospace companies acting as a “consortium” on the project would help reduce cost and company risk. Similarly, a parallel partnership in the civil transport market could be built, bringing together the specialties of Boeing, Lockheed and Pratt & Whitney to share in the development of the HSCT/SSBJ. The two major obstacles hampering HSCT development—noise control and cost per seat-mile (10% over normal fare) would be not be a factor in producing its bomber counterpart. Bomber production would further develop and “operationalize” propulsion systems, advanced materials and structural designs which could then be mapped to a civil transport and SSBJ. If the military bomber requirements would permit a close mapping of fuselage, wing and engine design, the production cost of both the civil transport and bomber could be reduced.

Finally, military interest in HSCT technology could push its developmental timeline forward, perhaps closer to a 2010 date predicted by NASA in Table 2. Not only would our American aircraft manufacturing companies stand to gain a huge advantage in the transoceanic market, but the military gains too by tapping into this civil resource as outlined in Chapter 3.

Notes

¹ John. T. Correll, “The B-2 and beyond,” *Air Force Magazine* 81, no. 7 (July 1998): 30.

² Ibid., 31.

³ John A. Tirpak, “Mission to Mach 5,” *Air Force Magazine*, January 1999, 28.

⁴ Ibid., 29.

⁵ Report To The Congressional Committees, *National Aero-Space Plane* (Washington DC: Government Printing Office), 47-50.

⁶ Tirpak, 30.

⁷ Ibid., 30.

⁸ David Baker, “Global Reach And Aerospikes,” *Air International*, February 1998, 106.

Notes

⁹ Tirpak, 30.

¹⁰ Ibid., 30.

¹¹ Baker, 109.

¹² Tirpak, 31.

¹³ “Hypersonic Experiment to Piggyback on Satellite Launch,” *Aviation Week and Space Technology*, 14 April 1997, 65.

¹⁴ Ibid., 65.

¹⁵ Correll, 31.

¹⁶ Alan Wilhite, and Robert J. Shaw, *NASA's High-Speed Research Program - Revolutionary Technology Leaps to Eliminate Barriers for Affordable Supersonic Travel*, August 1997, n.p., on-line, Internet, 12 August 1998, available from http://oea.larc.nasa.gov/HSR/aa_article.html.

Chapter 5

Conclusions and Recommendations

The High-Speed Research program holds vast potential for the future of both the civil market and the military. Though its progress is snagged on meeting aggressive noise and ticket price goals, the High-Speed Civil Transport could bring a remarkable capability to both the civil and military user. Military supersonic transportation fits hand-in-glove with our National Military Strategy of “shaping” the international environment, rapidly “responding” to a full spectrum of crisis and “preparing” now for an uncertain future. Part of preparing for the future means shoring-up our aging bomber force and the HSR/HSCT program may provide an inexpensive, long-range strike platform. What’s more, investing in such a program could have other positive outcomes for our nation. *First*, much of this high-speed technology could help the US move towards hypersonic flight in a controlled, step-by-step manner. These hypersonic vehicles could give the US military a decisive advantage in cruise missile capabilities, reconnaissance platforms, and rapid response vehicles. As for the US space industry, an air-breathing single-stage-to-orbit (SSTO) hypersonic vehicle would allow for a virtual monopoly of the low earth orbit market and on-demand access to space. *Second*, investing in the program would stimulate the civil production of a supersonic transport and business jet, perhaps speeding-up its service entry and thus providing the military with an excellent rapid-response transport.

USTRANSCOM, Headquarters AMC and those agencies responsible for rapid deployment and high speed transportation should further investigate the viability of both the HSCT and the SSBJ for military operations. Furthermore, USAF HQ Future Requirements—Bomber Division should investigate the HSR program's advances with the HSCT to determine if it has potential in the development of a future bomber.

Appendix A

HSCT Burn Techniques

The following two burn methods work differently, but the key to both is burning fuel such that it avoids excessive flame temperatures (more than 3,000° F) which produce NO_x at a high rate:

“Lean Premixed Prevaporized” Method

This concept mixes fuel and air upstream of the burning zone and allows sufficient time for the fuel to adequately vaporize. The vaporized fuel then enters the combustion chamber and ignites downstream of a flame stabilizer where the mixture moves at a slower rate.

“Rich Burn-Quick Quench-Lean Burn” Method

This combustor works in two different stages. First, excess fuel is injected and burned with relatively small amounts of air, this “rich burn” significantly reduces the NO_x levels via chemical reactions. Then, in the second and final fuel-lean stage, air is quickly and uniformly added downstream to finish-off the burning cycle.

Studies have shown via NASA’s Lewis Research Center, that either concept can cut NO_x emissions by 90 percent.¹ Current studies show that with a mature fleet of 1,000 HSCTs flying at Mach 2.4 and a combustor emissions index of 5 grams of NO_x per kilogram of fuel burned, a range of -0.7 percent to +0.1 percent ozone impact occurs, where positive numbers actually mean

the *creation of ozone*. This data was derived from five 2-dimensional atmospheric models. As a comparison, the Concorde emissions index is approximately 20.²

Notes

¹ NASA. *HSR Propulsion Project Overview*, 13 December 1997, n.p.; on-line, Internet, 5 August 1998, available from <http://www.lerc.nasa.gov/WWW/HSR/HSROver.html#A.1>.

² Alan Wilhite, and Robert J. Shaw. *NASA's High-Speed Research Program - Revolutionary Technology Leaps to Eliminate Barriers for Affordable Supersonic Travel*, August 1997, n.p., on-line, Internet, 12 August 1998, available from http://oea.larc.nasa.gov/HSR/aa_article.html.

Appendix B

NASA's eXternal Visibility System (XVS)

To enhance the HSCT's performance, NASA is planning on eliminating "nose droop" during takeoff and landing by using a revolutionary synthetic vision system. Regarding this system, NASA stated the following:

These displays would use video images, enhanced by computer-generated graphics, to take the place of the view out the front windows. The envisioned eXternal Visibility System (XVS) would guide pilots to an airport, warn them of other aircraft near their flight path, and provide additional visual aides for airport approaches, landings and takeoffs. Currently, supersonic transports like the Anglo-French Concorde droop the front of the jet (the "nose") downward to allow the pilots to see forward during takeoffs and landings. By enhancing the pilots' vision with high-resolution video displays, future supersonic transport designers could eliminate the heavy and expensive, mechanically-drooped nose. Eliminating the drooped nose could lower the overall weight of the aircraft, lowering the cost of each flight. In addition, a fixed nose design with an XVS would allow for a longer nose, reducing drag and resulting in additional fuel and weight savings. An XVS also could provide safety and performance capabilities that exceed those of unaided human vision.¹

XVS Flight Tests. Part of the HSR-2 Program includes both flight and ground vehicle tests of two preliminary external vision display systems. "Windowless" landings were also accomplished. Flight Test Series I, which ended in January of 1996, involved a NASA Boeing 737 equipped with a windowless research cockpit in the passenger cabin and a Westinghouse BAC 1-11 avionics test aircraft . These aircraft conducted approximately 20 test flights primarily investigating the suitability of the XVS sensors to detect other aircraft and ground objects during landing approaches, cruise, and airport holding patterns. Pilots also flew approximately 90

approaches and landings from the NASA 737's windowless research cockpit. These flights tested the pilot's ability to control and land the aircraft relying only on sensors and computer-generated images, including various symbology, on the XVS display.² See Figure 11.



Source: NASA Langley Research Center. Image # EL-1998-00169.

Figure 11. External Vision System Cockpit

NASA also stated, "...the first XVS flight test series gave researchers confidence that a future supersonic passenger jet could indeed be flown without forward facing windows in the cockpit."³ When pilots taxi the future supersonic passenger jet they will do so sitting nearly sixty feet in front of the forward landing gear. Engineers are currently working to better understand what difficulties may arise during taxi due to this significant distance. A full-scale ground test vehicle called the Surface Operations Research/Evaluation Vehicle (SOREV) will help engineers determine what sort of visual aids a pilot will need to get the jet to the runway and back.⁴

Notes

¹ NASA. *NASA's High-Speed Research Program - The External Vision System Concept*, March 1998, 1; on-line, Internet, 12 July 1998, available from <http://oea.larc.nasa.gov/PAIS/HSR-Cockpit.html>.

² Ibid., 1.

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³ Ibid., 2.

⁴ Ibid., 2.

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